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A DYNAMIC EVALUATION OF THE INTEGRATED AVIONICS CONTROL SYSTEM --ETC(U)
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A DYNAMIC EVALUATION OF THE INTEGRATED AVIONICS CONTROL SYSTEM (IACS)

William B. DeBellis

February 1980
AMCMS Code 612716.H700011

U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

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The Integrated Avionics Control System (IACS) was developed to reduce crew member workload and save cockpit space by controlling all airborne communication systems from a single control panel. This investigation compares the IACS with a suite of standard communication radios through the use of computer graphics, mockups, and hardware. It was concluded (1) that there is a definite savings in cockpit space, (2) the crew workload is reduced, and (3) cockpit "bookkeeping" related to communications is a significant portion of the workload.

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A DYNAMIC EVALUATION OF THE INTEGRATED AVIONICS CONTROL SYSTEM (IACS)

William B. DeBellis

February 1980

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EXECUTIVE SUMMARY

The Integrated Avionics Control System (IACS) was developed by the Aviation Research and Development Activity (AVRADA). The purpose of the development was to reduce crew workload by using preset channels and to control all on-board avionics systems from a single interactive control and display device. Two systems are currently undergoing competitive development by separate contractors.

The US Army Human Engineering Laboratory (HEL) structured an investigation which compared both competitive systems on interactive graphics and also compared the IACS with a suite of standard avionics in an advanced attack helicopter (AAH) mockup. These comparisons were based on a simulated mission communication scenerio which required the subjects to operate all communication and navigation radios plus the radar transponder.

The following results have been obtained:

1. The average time for manipulating the IACS controls was 8.6 seconds per frequency change as compared to 9.9 seconds for operating standard avionic controls. This represents a 13 percent (1.3 seconds) savings in time and is statistically significant to the 0.02 level.

2. There is approximately a 28 percent savings in console space when the IACS is integrated into the AAH cockpit.

3. The time consumed for the cockpit bookkeeping is considered a significant portion of the communication workload. Depending on the type of communication, this time is an average of 30 to 67 percent of the total time necessary to communicate.

4. The lack of guidance as to the utilization of multiple net variables in voice security creates a gap in the doctrine related to a CEOI. This issue impacts the communication effectiveness of the aircrew.

Under the conditions and definitions of workload in this experiment, the IACS generally demonstrated a reduction in time required to access radio frequencies over conventional separated radio heads. A validation of IACS must be conducted in an operational setting to ascertain the benefits of this workload reduction.

PREFACE

A great amount of preparation is always required even for the most simple investigation. Two persons should be singled out for their contributions: Mr. James Gombash for programming the integrated avionics control system logic on the interactive graphics, and Mr. Allen Tucker for constructing a detailed advanced attack helicopter mockup.

CONTENTS

EXECUTIVE SUMMARY 1

PREFACE 2

INTRODUCTION 5

DESCRIPTION 5

METHOD 7

- Experimental Design 7
- Procedure 8
- Flight Evaluation 10
- Subjects 12
- Training 12
- Timing 13

RESULTS AND DISCUSSION 13

- Phase I 13
- UHF Transceiver 16

- Phase II 17

SPECIAL INVESTIGATIONS 22

- Manual Entry 22
- Hardware Data Run 23
- Flight Evaluation 24

CONCLUSIONS AND RECOMMENDATIONS 24

- Conclusions 24
- Recommendations 25

APPENDIXES

- A. Data From Phase II 27
- B. Mission Communications CEOI Handout 32
- C. Communications Diagrams 41

LIST OF ABBREVIATIONS 51

FIGURES

1. IACS(A) 6
2. IACS(B) 6
3. Use of Light Pen 8
4. Use of Controls 8
5. IACS(A) As Presented On the Interactive Display 9
6. IACS(B) As Presented On the Interactive Display 9
7. AAH Mockup Looking Aft 10
8. AAH Mockup Looking Forward 10
9. The IACS Installation in a UH-1 Helicopter 11
10. Procedure Used to Determine Operating Time 14
11. Excerpt From the Abbreviation CEOI 17
12. Call Signs, Frequencies, and Suffixes From a CEOI 18
13. Forward Crew Station with Standard Avionics 19
14. Forward Crew Station with IACS 19
15. Aft Crew Station with Standard Avionics 19
16. Aft Crew Station with IACS 19

TABLES

1. AAH Avionics Package 7
2. Subject Data 12
3. Operating Time 15
4. Error Rate 15
5. Processing Time 15
6. Communication Time 16
7. Time to Select a New Frequency 21
8. Preset Versus Manual Frequencies 21
9. Operating Time by Radios 21
10. All Manual Versus Normal Engry Subject 4 on IACS(B) 23
11. Simulated Mission on IACS(A) Installed Hardware 23

A DYNAMIC EVALUATION OF THE INTEGRATED

AVIONICS CONTROL SYSTEM (IACS)

INTRODUCTION

Helicopter crew stations are continually expanding and becoming more complex in the number of controls and displays presented to the aircrew. The need to provide secure and sometimes redundant communications on multiple frequency bands has resulted in a steady increase of avionics control and displays in the cockpit. As a result, not only have crew stations become more complex, but the aircrew workload has also increased. Steps are being taken to eventually provide a fully integrated crew station specific to the Army's mission. Integrating the avionics is one logical step.

The purpose of the Integrated Avionics Control System (IACS) is to reduce pilot workload and simplify the crew station through the use of preset channels and a central data entry device. The IACS was developed by the Aviation Research and Development Activity (AVRADA) and two systems are presently undergoing competitive development. The US Army Human Engineering Laboratory (HEL) has supported AVRADA during the development of both systems.

The objective of these experiments was to investigate the IACS in conjunction with communication security devices and a mission scenerio. The investigations were conducted in two major phases: Phase I compared the two competitive systems through the use of interactive computer graphics while Phase II compared the IACS with standard avionics in the Advanced Attack Helicopter (AAH) mockup at HEL. The comparison data from Phase I are contained in a separate report, but because of the competitive status of the development, this report contains summary data from Phase I.

DESCRIPTION

Figures 1 and 2 display the primary control panels of the IACS under consideration.

Figure 1. IACS(A).

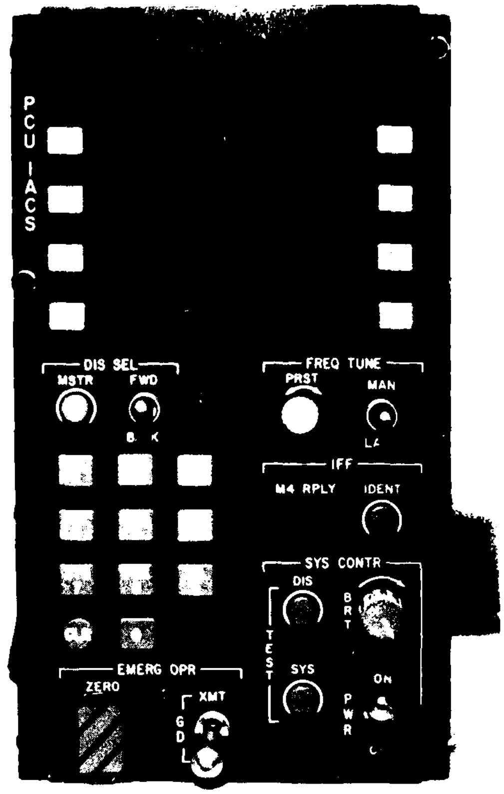


Figure 2. IACS(B).

Physically, the IACS consists of primary and secondary control panels and status displays which are used to operate all on-board avionics systems. The system is interconnected with control units through dual redundant MIL-STD-1553A Serial Data Buses. The system can control any number of transceivers which are modified to be digitally addressed.

A full description of the complete physical and operational aspects of both IACS is too lengthy to be contained here. Consequently, only selected features relating to this investigation are presented.

Basically, the operator can select various radio functions which are presented through the use of a paging system and a data entry keyboard. These include selecting and setting up the individual radios and initializing them with the preset frequencies. Ten preset channels per radio are provided which associate the frequency with the correct voice security net variable.

Once the avionics have been set up, a status page is brought up which displays the frequency and channel that has been selected for each on-board system. Typically, to communicate with a new party, the operator looks up the new channel; selects the proper line key and increments the display line to the new frequency.

The configuration of the IACS used during this investigation included the AAH communication package and a VOR as shown below in Table 1.

TABLE 1

AAH Avionics Package

Quantity	Description
2 VHF FM	ARC 114
1 VHF AM	ARC 115
1 UHF AM	ARC 164
1 ADF	ARN 89
1 VOR/ILS	ARN 123
1 IFF	APX-72 or 100
4 COMSEC	KY-58

METHOD

Experimental Design

The investigation was conducted in two phases. Phase I was a direct comparison of the two competitive IACS, and was accomplished on an interactive graphics system. The design was a split-plot factorial with assigned subjects. This particular design was chosen because a preliminary analysis indicated that cross training of subjects on both IACSs would complicate the investigation due to differences in data entry. The *dependent variables* were both time and frequency of errors. No secondary tasks were planned to load the operator.

Phase II was designed to compare a generic IACS with a suite of standard radios in the HEL AAH mockup. The experimental design was an overall dependent t analysis on the dependent variable of time. The design was chosen because the subjects operated both the IACS and the standard avionics.

Data were also obtained on (1) a flight using operational IACS hardware, (2) operating the simulated IACS in an all manual mode, and (3) operating IACS(A) hardware with the Phase I and II mission scenerio.

During all phases, comments and suggestions for improvement were recorded.

Procedure

During Phase I, the subjects sat in front of a computer-driven graphics display with the experimenter behind them. On the console shelf were a scratch pad and an abbreviated CEOI which contained the parties, frequencies and net variables to be preset for the mission. Additional call signs were also given which might have to be used if the message requested the operator to contact a party who was not previously preset. The subject wore earphones and had a set of control buttons located on the right side. Figures 3 and 4 shows a subject using the interactive graphics and light pen.

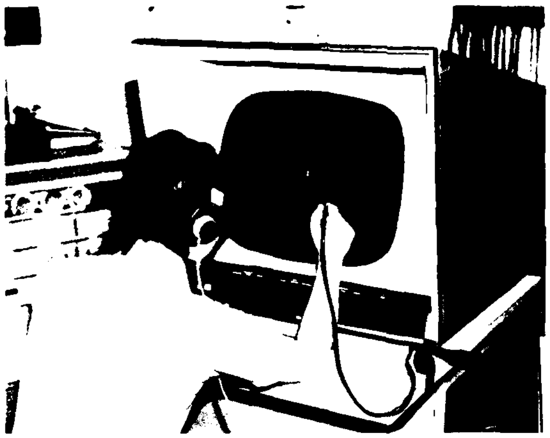


Figure 3. Use of light pen.

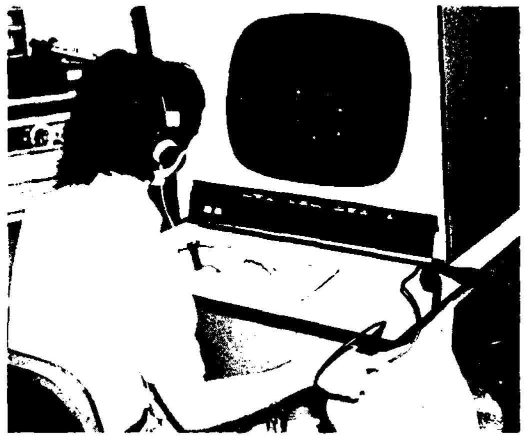


Figure 4. Use of controls.

A written set of instructions pertaining to the simulated mission to be flown was given to each subject along with a mission briefing. The voice tape contained messages which followed the mission. The tape contained messages to contact parties, to navigate to different automatic direction finder (ADF) beacons, and to make transponder changes. The majority of the changes were accomplished through preset operation; however, the subject was also required to enter frequencies and codes manually. Appendix B contains a list of the mission messages, the abbreviated CEOI, and the preliminary hand out.

Figures 5 and 6 display the competitive IACSs as they were presented on the interactive display.

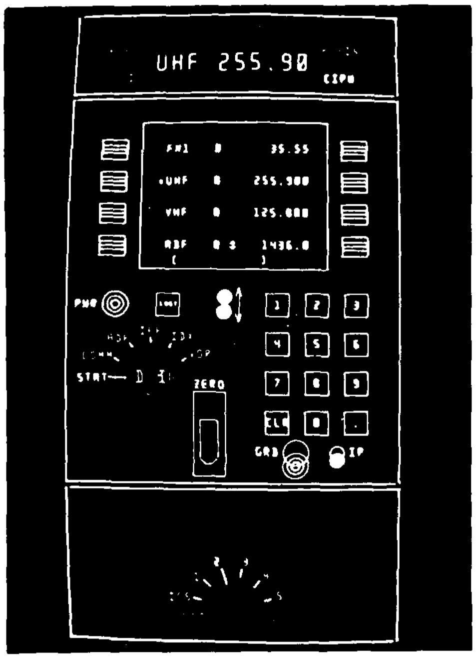


Figure 5. IACS(A) as presented on the interactive display.

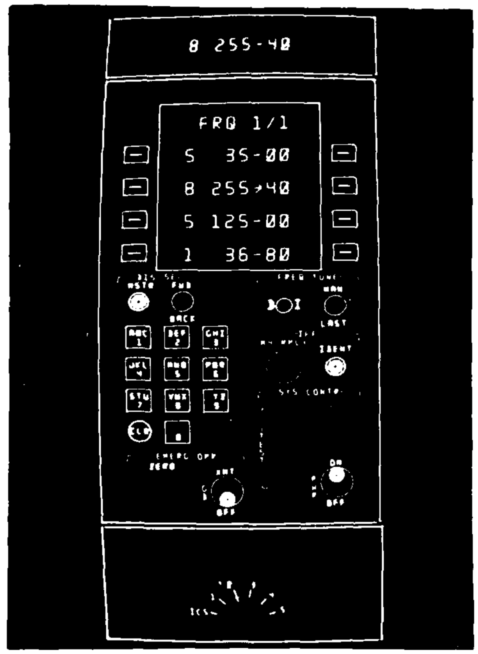


Figure 6. IACS(B) as presented on the interactive display.

In each figure, the top panel is the status display, the middle panel is the primary control panel, and the lower panel is the intercommunication system (ICS) panel. The ICS panel is not part of the IACS but must be used to select transmitters.

The mission communication scenerio was structured to simulate a flight from division rear to the FEBA. It was selected instead of a battle scenerio because of an increased need to operate avionics equipment.

As a trial started, the subject heard the first message: the tape would stop and the subject would acknowledge the message by pressing any button to the right side. This simulated an acknowledgement which meant the message was understood. The subject would either remember which preset a party was assigned or refer to the CEOI before operating the avionics systems. When everything was correctly set up, the subject would press a button to simulate transmitting. If the proper frequency, net variable code, and ICS setting were selected correctly, the tape would automatically restart with a new message. If the tape did not restart, no message would be heard and the subject would have to determine the source of error, correct the error, and attempt to establish communications.

Two different CEOIs were used on alternate runs to simulate the normal daily CEOI changes; however, data was obtained with only one CEOI.

The computer recorded the times that every function switch or button was operated and the page being displayed on the primary control panel.

The procedure for Phase II was similar except that the subject did not have to acknowledge the message and was permitted to operate the avionics as soon as enough of the message was understood to do so. The subject sat in the AFT crew station of the AAH mockup, Figures 7 and 8, and operated both the IACS mockup and the Standard Avionics on alternate runs.

Figure 7. AAH mockup looking aft.

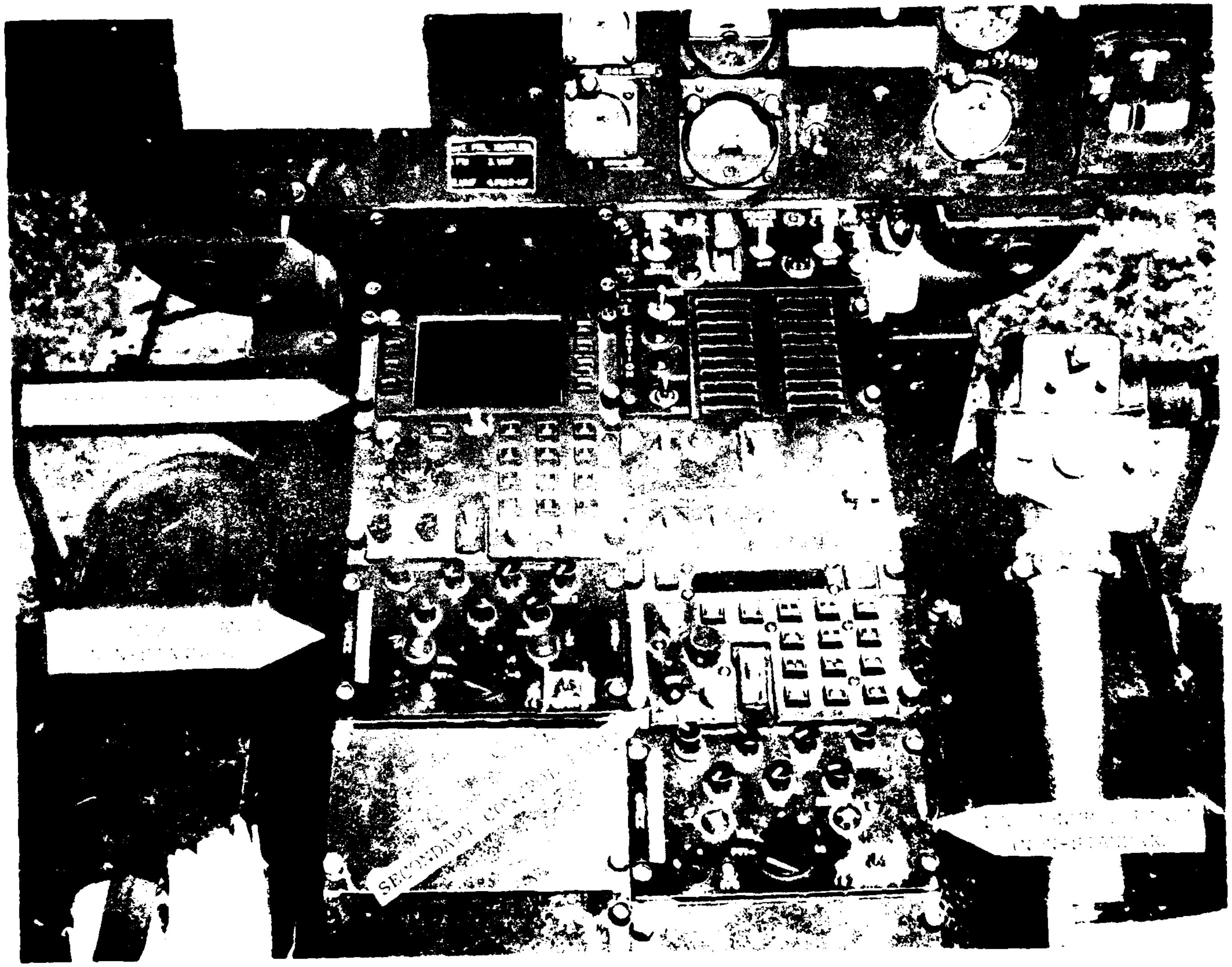
Figure 8. AAH mockup looking forward.

Data, which consisted primarily of time and errors, was obtained on video tape with a clock placed in the camera's field of view. Two data runs were obtained per subject. Errors could not be recorded, except for gross reach errors, since the controls were not instrumented to record activations. Phase II was accomplished after Phase I, which gave subjects experiece on the IACS.

Flight Evaluation

The IACS(A) was installed in a UH-1 Helicopter by AVRADA as part of their demonstration of the capabilities of the system. The IACS equipped helicopter was flown to the HEL so that the hardware could be evaluated and demonstrated. Figure 9 shows the UH-1 installation.

Figure 9. The IACS installation in a UH-1 helicopter.



The ICS panel shown is developmental and contains seven individual volume controls which also function as receiver switches.

Subjects

The subjects were active and non-current military pilots and civilian engineers located at Aberdeen Proving Ground. Table 2 lists details about each subject.

TABLE 2

Subject Data

Subject	Age	Rotary Wing Hours	Fixed Wing Hours	Last Logged Time (Yrs)	Rank	Assigned to Test Phase I	Assigned to Test Phase II
1	31	1500	0	Current	CPT	A*	Y
2	35	2600	600	Current	MAJ	B	Y**
3	50	0	2000	2	LT	A	Y
4	52	300	3100	1	MAJ	B	Y**
5	45	0	500	1	Civ	B	N
6	42	40	700	Current	Civ	B	N
7	55	0	6000	16	LTC	B	N
8	34	2500	25	1	CPT	A	Y
9	33	2500	10	4	MAJ	A	Y

*Individual IACS'S
**Subjects did not complete data run

The subjects had a limited amount of previous experience with the use of the CEOI or KY-58 voice security devices. Additional training was provided to subjects in these areas.

Training

Training was accomplished on the interactive graphics display because errors could be controlled. The use of the display and control devices, the purpose for the investigation and the nature of the simulated mission were explained. Approximately 1 hour of "hands-on" operation was accomplished in three sessions to demonstrate how IACS could be used efficiently. During this time, the use of CEOI and the KY-58 device was explained. The subjects then completed 3 to 6 hours of instructional sessions using the taped mission scenerio. Only the final session was used to gather experimental data even though data were collected on all runs. The operating time on preset frequencies was used to indicate if the subjects were trained. Training was considered adequate when operating time on preset frequencies reached an asymptote.

Timing

Operating time was the primary dependent variable (Figure 10). It is defined as follows: For Phase I of this investigation, it is the time from the first switch activation (g) to the initiation of the transmit switch (I); for Phase II, it is the time from when the pilot reached for the first operation (F) to the initiation of the transmit switch (I), because switch activation was not automatically recorded. Included in the operating time is the time from the last switch operation (H) to the initiation of the transmit switch (I). During this time, pilots checked the setting on their avionics and therefore, this time was dependent on the type and format of the displayed information. Also included in the operating time was the time required to change transmitters on the ICS panel and the time required to interface with speech security equipment.

The operating time was not just a simple measure of how fast buttons could be pushed, but instead, reflected the interaction with both the ICS panel and requirements for speech security.

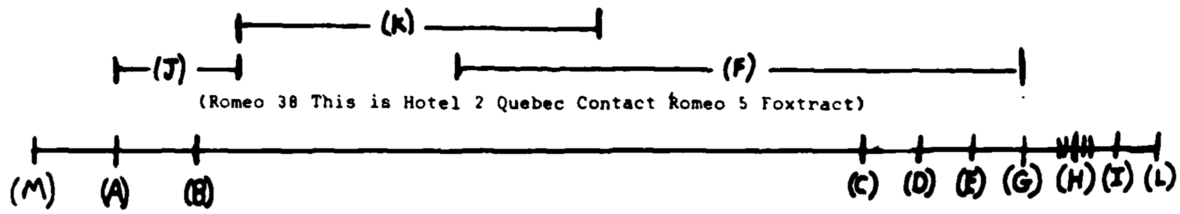
The time to look up information in the CEOI and knee-pad was also measured. For the purpose of this investigation, it was called processing time. Difficulty occurs in selecting the proper definition since the subjects begin to both mentally encode information before voice transmission begins, and physically start to look up information before the entire message has been completed. The listener is alerted in various degrees by the first breaking of the squelch, the qualities of the background hiss and preambles to a secured transmission, and the timbre of a familiar voice. In addition, the training and experience of the pilots is reflected in the organizing and placement of reference materials in the cockpit.

Processing time during Phase I was measured by requiring the pilots to listen to the complete message and to respond to the message with a "Roger" as an indication that the message was understood. The "Roger" (time fiducial (E)) had to be made before any key function became active. Processing time was, therefore, forced to occur after the message was completed and measured from the ending of the tape message (D) to the beginning of the first entry (G). This included as much as possible of the mental encoding time. Processing time did not start with the beginning of the message tape (A) because the message length from (A) to (D) was variable from message to message and its inclusion into the statistics would be an additional source of variance.

RESULTS AND DISCUSSION

Phase I

Summary data are described in the tables below. The data are averages of times and errors when combining the results of both IACS configurations used in Phase I. Direct comparison of Phase I and Phase II experimented results must be done cautiously because the Phase I experiment used a light pen to actuate the system while the Phase II experiment used a mockup of push button actuation.



Time

(A) Tape Play Back Starts Up
(B) Beginning of Voice Message
(C) Voice Message Ends
(D) Tape Unit Stops
(E) Operator Acknowledges Message
(F) Operator Reaches for First Operation
(G) Operator initiates First Operation
(H) Individual Switch Operation
(I) Operator Initiates Transmit Switch
(J) Operator begins to Process Information
(K) Operator begins to Respond to Message
(L) End of Data Run
(M) Beginning of Data Run

Figure 10. Procedure used to determine operating time.

Table 3 shows the mean times required to operate the IACS. The error free row displays the mean time to operate when errors in operation were excluded from the data; the error-only row displays the mean time to clear an error and recommunicate.

TABLE 3

Operating Time
(Seconds)

	Presets	Manuals	ADF Radio	IFF Transponder	ICS Only
Error Free	10.3	27.7	12.0	9.5	4.4
Error Only	42.9	52.8	----	---	---

Table 4 shows the error rate. It is the total number of errors divided by the total number of messages.

TABLE 4

Error Rate
(Errors Per Message)

	Presets	Manuals	ADF Radio	IFF Transponder	ICS Only
Error Rate	0.15	0.37	0.00	0.06	0.05
Total Messages	99	35	45	36	45

Table 5 shows the processing time which the subjects took before they started to operate the system.

TABLE 5

Processing Time
(Seconds)

Presets	Manuals	ADF	IFF	ICS
17.7	19.3	6.3	4.5	6.7

Table 6 shows the communication time rounded to the nearest second which combines both Tables 3 and 5.

TABLE 6

Communication Time
(Seconds)

	Presets	Manuals	ADF	IFF	ICS
Error Free	28	47	19	14	10
Error Only	61	72	--	--	--

As shown in Table 3, the time to operate the IACS with a manual frequency is approximately three times longer as the time required to use preset operation. When the processing time is included, the time to communicate with a manual frequency is approximately twice as long as the time to communicate with preset frequencies. These differences are both of practical and statistical significance and reflect the added tasks required of the manual entry procedure. The sequence flow diagrams for a typical request to communicate are contained in Appendix C. These diagrams display the number of steps for preset and manual frequency operation for various avionic configurations.

The IACS were designed to function primarily with preset frequencies. The use of manual frequencies was considered secondary during the IACS development; however, provisions to enter manual frequencies when operating with presets were provided.

Much of the time required to enter manual frequencies resulted from the difficulty encountered in cockpit "bookkeeping." This "bookkeeping" necessitated looking up voice security net variables on the CEOI and paging through the IACS to set them in.

In addition, no doctrine exists to correlate calling units with radio frequency or voice security net variables. An abbreviated CEOI was designed for this experiment. A sample of the CEOI is shown in Figure 11 and Appendix A.

Figure 11 is an excerpt from a CEOI instructional manual.

UHF Transceiver

Channel	Party	Call	Frequency	Net Variable
6	Forward Air Controller	Y4M05	379.000	2
7	Division ATC	Y4M07	305.125	4
8	#2 FARP	K8V01	236.400	3
-	Division Airfield	X1J60	305.750	2

Figure 11. Excerpt from the abbreviation CEOI.

The error rate for manual entry is about three times greater than that for preset as indicated in Table 4. This further corroborates the times of Table 3 which indicate that with a greater number of tasks to perform, the operator will be prone to commit more errors.

The IACS was initialized with 50 preset frequencies which is more than would be needed under operational conditions. However, this was designed into the experiment to assess the time necessary to initialize the full capability of the IACS. As a result, some of the errors that occurred were caused by the subjects looking up the wrong party in the CEOI in response to the message.

In any event, the subject took a mean of 900 seconds (15 minutes) to enter all 50 presets and set up the suite of avionics.

During the mission, there were requirements for the subjects to change only the ICS setting. These were apparently recognized by the subjects since the mean average time for the operations was 4.4 seconds compared to 10.3 seconds for operating both presets and ICS functions.

Phase II

This phase of the investigation compared the IACS with the AAH Standard Avionics. The initial task was to first integrate the IACS into the helicopter to facilitate communication. The second task was to assess any change in workload using the Phase I experimentation procedure.

The AAH contains two crew stations in a tandem configuration with the pilot in the AFT crew station. The avionics, including navigation receivers, are split between the two crew stations with no redundancy except for VHF FM communication and ICS capability. Figures 13 and 16 show both crew stations with and without IACS.

PROTECTIVE MARKING

KTV 6ØØ A CALL SIGNS 1Ø
2/14 CAV SQDN

	Ø1	Ø2	Ø3	Ø4
2/14 CAV SQDN	Q4F	M5C	R8K	P2M
HHT	DØB	W2H	K4D	HØQ
A TRP	04I	Y9A	NØX	W6R
B TRP	Q7D	P2U	H1B	P8L
C TRP	T1S	Z1D	B7C	J3E
D TRP	H4M	D9V	K7T	VØC
CAV SPARE 1	K8U	TØ1	M9U	X8D
CAV SPARE 2	Q9T	R5F	Y5A	X1J
CAV SPARE 3	XØA	Y4M	H9E	MØF
CAV SPARE 4	X5G	G7B	G7M	H2G
MEDEVAC	P8K	V4X	F90	O40

To use the suffix properly, we must add it to the already established call sign. Example:

ZID - Call Sign.
ZID56 - Call Sign with suffix.
ZID56H - Call sign with suffix and expander letter.

PROTECTIVE MARKING

KTV 6ØØ A FREQUENCIES 1Ø
2/14 CAV SQDN

	Ø1	Ø2	Ø3	Ø4
2/14 CAV CMD	36.95	32.75	37.7Ø	31.55
RETRANS	69.8Ø	69.7Ø	69.6Ø	69.8Ø
2/14 CAV O&I	39.8Ø	66.75	6Ø.95	68.85
2/14 CAV A/L	4Ø.7Ø	39.65	42.95	36.35
+A TRP CMD	4Ø.55	71.1Ø	34.35	56.15
+B TRP CMD	34.55	69.55	46.9Ø	72.7Ø
+C TRP CMD	69.55	46.9Ø	57.35	55.95
D TRP CMD	32.6Ø	67.95	6Ø.55	38.6Ø
REDEYE SEC	47.Ø5	65.35	48.6Ø	57.85
CAV SPARE 1	46.85	38.95	3Ø.55	3Ø.35
CAV SPARE 2	33.75	45.85	47.75	46.85
CAV SPARE 3	47.75	42.6Ø	33.4Ø	44.35
+MEDEVAC P	36.3Ø	36.3Ø	36.3Ø	36.3Ø

PROTECTIVE MARKING

SUFFIXES-TIME PERIOD 04 2

Ø1	CHEMICAL OFF	31	FINANCE
Ø2	G4/S4	32	HELO/COBRA #5
Ø3	ADC-2	33	DACE
Ø4	ASST FS COORD	34	G2/S2 AIR
Ø5	G3/S3 AIR	35	LNO #2
Ø6	VEH/SQD/SEC/TANK #9	36	METRO
Ø7	FSE	37	VEH/SQD/SEC/TANK #2
Ø8	VEH/SQD/SEC/TANK #3	38	HELO/COBRA #4
Ø9	HELO/COBRA #6	39	
1Ø		4Ø	AVIATION OFF
11	G1/S1	41	LNO #6
12	AMMO TRAIN	42	HELO/COBRA #9
13	VEH/SQD/SEC/TANK #4	43	VEH/SQD/SEC/TANK #6
14	PMO	44	OPS NCO
15	AMMO OFF	45	NET CONTROL STATION
16	ASA SIGSEC	46	FO/TACP/RECON #2
17	ALTERNATE	47	GCA
18	CHAPLAIN	48	FO/TACP/RECON #1
19	C-E OFF	49	FIRST SERGEANT
2Ø	FDC	50	HELO/COBRA #1
21	RADAR	51	SAFETY OFF
22	ALTN NCS	52	HELO/COBRA #7
23	ENGINEER OFF	53	G2/S2
24		54	AIR FORCE LNO
25	SVC PLT LDR	55	SURGEON/MED OFF
26	CHIEF OF STAFF/XO	56	HELO/COBRA #8
27	SP WPNS OFF	57	G5/S5
28	COMMANDER	58	VEH/SQD/SEC/TANK #8
29	G3/S3	59	
3Ø	PLT/SEC LDR	6Ø	FLT OPN

SUFFIXES 7 of 16 2

You must use all three items of the CEOI to find your call sign, frequency and suffix to enter your net.

Figure 12. Call signs, frequencies, and suffixes from a CEOI.

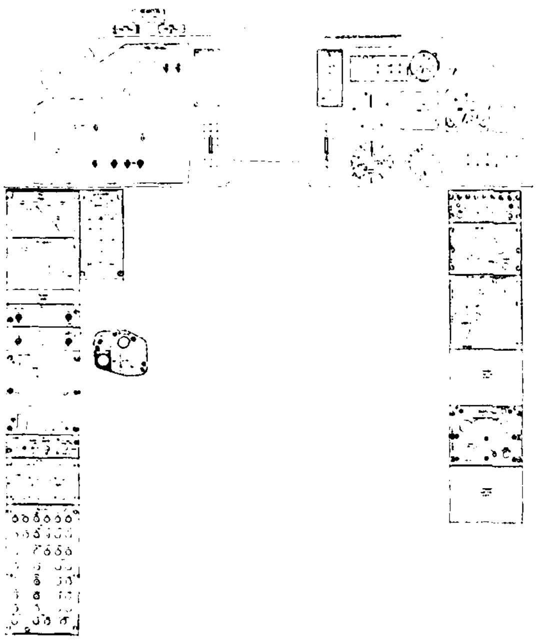


Figure 13. Forward crew station with standard avionics.

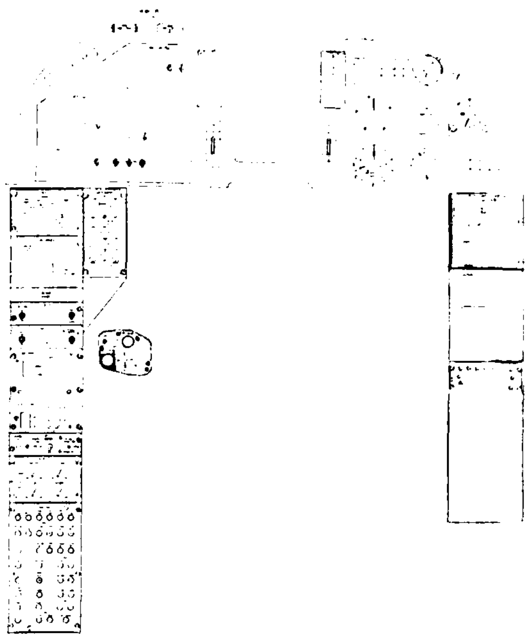


Figure 14. Forward crew station with IACS.

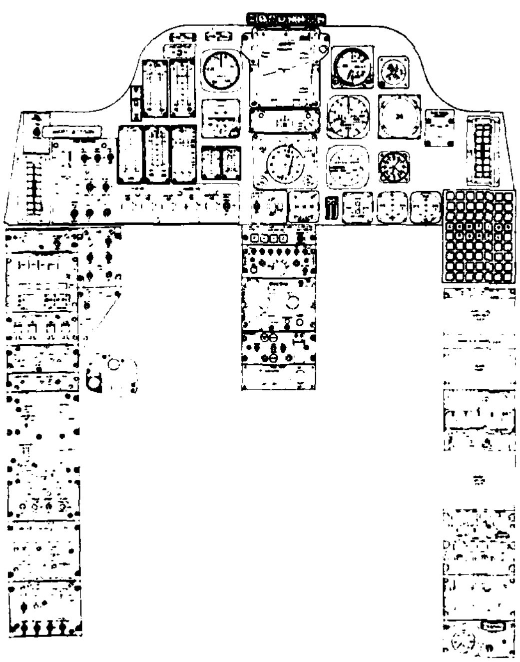


Figure 15. Aft crew station with standard avionics.

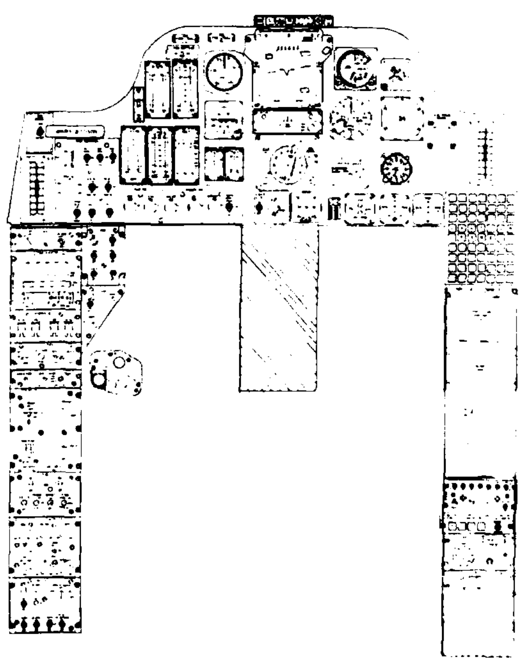


Figure 16. Aft crew station with IACS.

The IACS configuration selected for this test contained two primary control panels with no status or secondary control panels. This configuration gives both crew members the capability of taking over the complete communication and navigation tasks during any portion of the mission. The combined workload of the crew is reduced because either crew member may preprogram every radio before the need to change frequencies. In addition, the tasks can be handed off between each crew member on the basis of available time. As examples, during NOE flight, the pilot has virtually no free time to navigate or change frequencies and, conversely, during target acquisition and tracking, the gunner or second crew member has no time to keep up with communications and the helicopter's position.

During emergency situations, two features of the IACS also reduce workload. The first is that the IACS primary control panel contains a single toggle switch which when activated switches every radio to guard frequency and the transponder to the international emergency code. The second feature is another single switch which will "zeroize" all the COMSEC secure codes and preset frequencies on every radio. Again, both of these features can be activated from either crew station which means the crew member flying the helicopter does not have to remove a hand from the flight controls to find and select these functions on each radio and COMSEC device.

What remained to be determined was the effect this concept had on the time to communicate. After recognizing the cockpit panel space saving, it remained the objective of the Phase II experiment to determine time savings. To accomplish this task, the VHF FM radio was placed in the AFT crew station of the AAH so that a single pilot could operate all the communication equipment.

The overall result was a 1.3 second average reduction in operating time using IACS over standard avionics; this represents a 13 percent savings in time. The probability that this difference would occur by chance is less than 2 percent. This result was based on the mission communication load used during Phase I, and contains the ratio of preset and manual frequency requirements with navigation and transportation requirements interlaced described before.

To identify what was occurring, various comparisons were accomplished which divided the operating time into various categories. Table 7 shows the operating time when the data are organized to reflect what occurs when a new frequency must be selected during the mission. In effect, all data associated with simple ICS changes were deleted.

TABLE 7

Time to Select a New Frequency
(Seconds)

	Communication	ADF	IFF
AAH	11.7	6.9	11.5
IACS	9.4	7.5	8.5
Difference	2.3	(-) 0.6	3.0

Table 8 shows the operating time when preset and manual frequencies were compared.

TABLE 8

Preset Versus Manual Frequencies

	Preset	Manuals	Difference
AAH	10.6	15.6	5.0
IACS	7.3	15.2	7.9
Difference	3.3	0.4	---

Table 9 compares the operating time by individual radios.

TABLE 9

Operating Time By Radios
(Seconds)

	UHF Presets	UHF Manuals	VHF Presets	VHF Manuals	ICS Only	ADF	IFF
AAH	12.9	14.0	13.3	16.1	5.3	6.9	11.5
IACS	6.3	17.1	7.6	15.0	6.6	7.5	8.5
Difference	6.6	(-) 3.1	5.7	1.1	(-)1.3	(-) .6	3.0

When the data were divided, as in the above three tables, equal weight is given to each category during the analysis; i.e., in Table 7 communication time, IFF, and ADF operating times each contribute equally in the analysis even though the mission contained 12 requests to communicate, 4 requests to change IFF codes, and 5 requests to change ADF beacons. Again, refer to Appendix A for the complete statistical tables.

Referring to Table 7, when a new frequency or preset channel had to be selected, there was a 2.3-second time advantage using IACS. Additionally, the transponder can be operated an average of 3.0 seconds faster using IACS. The probability that these differences would occur by chance is less than 1 percent. Operationally, these times represent a 20 percent decrease in the time to select a new frequency and a 26 percent reduction in the time to operate the transponder. No advantage or disadvantage was found when operating the ADF radio.

Referring to Table 8, even though there was a 3.3-second time advantage using preset frequencies on the IACS, there was a 20 percent probability that this difference would occur by chance. The 10.6-second time shown for the AAH manual frequencies on the other radios for those communication requests were used as presets on the IACS. The probability that the 5.0- and 7.9-second differences shown between the manuals and presets would occur by chance is less than 1 percent.

Referring to Table 9, the majority of the FM communications changes were accomplished by using only the ICS switch. The 1.3 seconds advantage the AAH conventional avionics had over the IACS may have been the result of the ICS panel being poisitioned in the mockup just aft of the IACS panel. The subjects would hesitate in their response and seemingly want to change transmitters on the IACS instead of the ICS panel. In addition, the procedure to call up a preset frequency by entering a number and operating a line key led the subject to believe that the transmitter was also selected through selecting both the radio and preset channel on the IACS. It was anticipated that the operating times would favor the IACS since, in the conventional AAH avionics layout, the ICS is not conveniently located.

SPECIAL INVESTIGATIONS

Three ancillary investigations were conducted. The first was to determine the performance of a subject during Phase I using all manual entry on the IACS. The second was to determine the performance of a subject using the IACS hardware, and the third was an actual flight with the IACS hardware.

Manual Entry

During Phase I, one subject was concerned that using presets did not seem to offer any advantage. The simulated mission was then flown using no presets but instead, operating the IACS in a completely manual mode. Table 10 compares this subject's run with his normal run. These times were for error free operation.

TABLE 10

All Manual Versus Normal Entry Subject 4 on IACS(B)
(Seconds)

Access	Overall Mission	Presets	Manuals	AAF	IFF	ICS
Normal Entry	12.8	13.3	35.2	10.5	9.3	6.1
Manual Entry	10.4	-0-	14.4	10.3	9.3	3.8
Difference	+2.4	-0-	+20.8	+ .2	- .5	+2.3

The subject used a marked CEOI so that familiar calls were highlighted. With this fact in mind, a dependent t-analysis was performed on the subject's mission time. The result indicates that there is a .30 percent probability that the 2.4 second average time shown is due to chance which is not strong enough to conclude that the subject performed any better. In addition, the number of errors increased from three to five.

Hardware Data Run

The test apparatus used during Phase II was installed in the AVRADA IACS demonstration helicopter and a data run was obtained with the helicopter on the ground. The subject sat in the left seat and operated the IACS with his right hand. Timing was obtained by reviewing the video tape.

Table 11 compares the time required to operate the hardware with the results obtained during Phase I and II evaluations.

TABLE 11

Simulated Mission on ICS(A) Installed Hardware
(Times in Seconds)

	Overall Mission	Presets	Manuals	ADF	IFF	ICS
Phase I	---	9.9	27.1	10.4	9.2	4.6
Phase II	8.6	7.3	15.2	7.5	8.5	5.3
UH-1	8.9	5.8	13.7	14.8	13.9	2.5

Flight Evaluation

The AVRADA UH-1 Helicopter was instrumented with a video camera and voice recorder. An IFR flight was planned between Phillips Army Airfield, APG, and Cameron Station, Virginia. The mission was chosen because it entered the Washington, DC Terminal Control Area (TCA) and the helicopter would overfly five other airfield traffic areas. In addition, there would probably be a need to change frequencies 12 times with several transponder code changes.

The pilot preprogrammed the IACS presets in sequence with the first frequency placed in channel one and the last placed in the last channel.

The helicopter was flown by the pilot in the right seat while the copilot/navigator operated the IACS from the left seat. The following is a list of observation from this flight.

1. Within 20 minutes into the flight, manual frequencies were being used on both the VHF and UHF radios.

2. The secondary control panel was not used during the flight.

3. The status panel was not used during the flight. All information was being obtained from the single center console mounted primary display.

4. The copilit/navigator used the presets but continually checked that the correct frequency had been selected.

5. The IACS was utilized for all avionics and no back up radios were required.

6. No malfunctions occurred during the flight except that the VOR course deviation indicator (CDI) was not phased correctly. Apparently, this problem occurred before the helicopter arrived at APG.

The pilot/navigator offered the suggestion that the display contain an IFF line so that transponder codes could be entered without changing the display.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The IACS reduces console space required for avionics controls and displays by approximately 28 percent.

2. The IACS reduces the time required to access any given radio frequency by 1.3 seconds or 13 percent.

3. There is a gap in the operational doctrine as to the employment and structuring of CEOI with KY-58 type multiple net voice security devices. The "bookkeeping" in the cockpit, due to the present CEOI procedures, induces increased aircrew workload.

4. The use of IACS preset frequencies shows a clear advantage over conventional radio frequency selection techniques. However, the use of manual frequency selection in the IACS is not clearly advantageous when compared to conventional frequency selection. The likelihood of a mission being flown entirely on preset frequencies is remote.

5. These experiments indicate that there are improvements in the aircrew communication workload when using IACS. However, these results must be verified in an operational setting to ascertain the benefits of the workload reduction determined here.

6. These experiments indicate that the integration of cockpit controls and displays has potential benefit in workload reduction for future Army helicopters.

Recommendations

1. The addition of two more lines of information on the IACS display will enhance its utility to the aircrew.

2. The capability of entering the COMSEC net variable on the status page would simplify aircrew interaction.

3. In future development, the preprogramming of the communications and navigation requirements could be accomplished by inserting a "credit card" so that the IACS would be loaded with all necessary information including possibly a CEIO with alternate frequencies.

If this were accomplished, the display would show the unit or party that was selected instead of the channel, frequencies and radio (i.e. the crew member wants to communicate with "A Company," finds "A Company" assigned to Channel 27, selects 27, and places this on the top line. The display then shows "A Company" instead of UHF-305.725-8). The frequency and radio would normally change but "A Company" would always be assigned to Channel 27.

APPENDIX A

DATA FROM PHASE II

Data From
Phase II
Error Free Seconds

Message Count	Message Type	Radio Being Utilized	ICS Setting	Subjects S1 A	S1 I	S2 A	S2 I	S3 A	S3 I	S4 A	S4 I
1	-	FM	1	3	11	6	6	6	5	18.8	6.8
2	-	FM	1	10	9	7	2	5	5	14.4	5.5
3	-	UHF	2	21	7	17	14	6	4	44.0	13.0
4	-	UHF	2	12	3	10	6	5	5	13.2	7.2
5	-	UHF	2	14	4	2	2	3	2	14.5	3.2
8	-	VHF	3	13	8	11	12	14	5	10.2	10.0
15	-	VHF	3	22	7	14	9	26	4	19.5	6.5
19	-	UHF	2	10	11	17	8	9	5	8.6	5.6
24	-	FM	1	4	11	4	11	4	19	3.1	5.8
26	-	FM	1	7	8	3	14	6	3	8.8	4.6
28	-	VHF	3	9	7	6	6	6	11	4.7	5.9
30	-	FM	4	9	10	6	9	6	7	3.2	-
11	-	UHF	2	14	18	17	14	22	18	13.6	12.1
18	-	UHF	2	12	15	12	11	16	9	14.6	40.0
21	-	VHF	3	16	14	13	11	15	10	13.0	15.4
25	-	VHF	3	22	10	14	12	17	5	18.5	28.9
10	-	FM	1	11	9	9	3	7	3	11.9	16.5
12	-	FM	1	6	8	5	6	2	2	8.2	12.1
14	-	UHF	2	12	18	3	4	5	3	6.2	13.4
16	-	FM	1	5	6	2	3	3	2	1.0	5.7
20	-	FM	1	3	8	2	12	2	2	3.0	8.6
6	P	ADF	-	13	7	10	6	8	8	13.7	11.1
13	M	ADF	-	8	10	6	11	5	9	6.9	13.6
23	P	ADF	-	8	4	7	7	7	4	8.9	12.1
27	P	ADF	-	3	6	3	6	3	3	5.4	9.6
29	P	ADF	-	6	4	7	7	5	5	6.0	6.3
7	-	IFF	-	7	8	12	5	8	13	10.2	10.4
9	-	IFF	-	10	7	11	11	10	8	14.5	7.5
17	-	IFF	-	11	8	12	8	13	6	22.0	15.2
22	-	IFF	-	10	6	9	6	11	8	15.2	8.8

Analysis For Summary Table (G)
Seconds

	AAH		IFF					
	Communication	ADF	IFF	Communication	ADF	IFF	ΣΣS	(Σ S)²/P[illegible]
S1	9.93*	6.60**	11.00**	9.18*	7.40**	7.50***	51.61	443.9[illegible]
S2	10.37	5.60	10.70	7.50	5.80	8.75	48.72	395.6[illegible]
S3	12.37	7.60	9.50	9.56	6.20	7.25	52.48	464.64
S4	14.14	7.92	14.83	11.36	10.50	10.48	69.26	799.4[illegible]

	Communication	ADF	IFF	A	(A)²NG
AAH	46.84	27.72	46.03	120.59	1211.82
IACS	37.60	29.90	33.98	101.48	858.18
B	84.44	57.62	80.01		
(ΣB)²NP	891.26	415.00	800.20		

N=4 [illegible]
P=[illegible] [illegible]
[illegible]=3 NP=[illegible]

Source	SS	df	MS		F	P
Blocks	43.25	3	14.41	3/15	14.29	
Treatments	81.09	5	16.21			
A	15.21	1	15.21	1/15	15.08	.99
B	51.67	2	25.83	2/15	25.61	.99
AB	14.20	2	7.10		7.04	.99
Residuals	15.13	15	1.00			
Total	139.48	23				
Commo AT B1	10.67	1	10.67	1/15	10.59	.99
ADF AT B2	.59	1	.59	1/15	.59	
IFF AT B3	18.15	1	18.15	1/15	17.99	.99

* This is a mean average of 16 numbers
** " " " " " " 5 "
*** " " " " " " 4 "

Analysis For Summary Table (H)
Seconds

Subject	AAH Presets	AAH Manuals	IACS Presets	IACS Manuals	$\Sigma\Sigma S$	$\frac{(\Sigma\Sigma S)^2}{P}$
S1	11.17	16.00	8.00	14.25	49.42	610.58
S2	8.58	14.00	8.15	12.00	42.83	458.60
S3	8.00	17.50	6.25	10.50	42.25	446.26
S4	14.53	14.93	6.74	24.10	60.30	909.02

B	A Presets	A Manuals	ΣA	$(\Sigma A)^2 Nq$
AAH	42.28	62.43	104.71	1370.52
IACS	29.24	60.85	90.09	1014.52
B	71.52	123.28		
$(\Sigma B)^2 NP$	639.38	899.74		

N=4 PQ=4
P=2 NQ=8
Q=2 NP=8

Source	SS	df	MS	F	P
Blocks	52.78	3	17.59	1.65	
Treatments	189.01	3	63.00		
A	13.35	1	13.35	1.25	.72
B	167.44	1	167.44	15.72	.99
AB	8.20	1	8.20	.77	.02
Residual	95.85	9	10.65		
Total	337.64	15			

Fixed Model RBF 2x2
From 'KIRK' Page 239

Analysis For Summary Table (I)
Seconds

Catagory	Condition	Subjects S1	S2	S3	S4	ΣS/4	Sd	Δ	N_1
Overall Mission	A	8.57	8.00	10.36	12.16	9.9	1.7	1.3	30
	I	8.07	6.53	8.73	11.08	8.6	1.9		
Communication	A	8.57	8.80	11.19	11.88	10.1	1.7	1.4	21
	I	8.33	6.28	9.62	10.60	8.7	1.9		
Must Select A New FREGS	A	9.93	10.37	12.37	14.17	11.7	2.0	2.3	16
	I	9.18	7.50	9.56	11.36	9.4	1.6		
Using PRESGTS	A	8.58	8.00	11.17	14.53	10.6	3.0	3.3	12
	I	8.25	6.25	8.00	6.74	7.3	1.0		
Using MANUALS	A	14.00	17.50	16.00	14.93	15.6	1.5	0.4	4
	I	12.00	10.50	14.25	24.10	15.2	6.1		
UHF Radio	A	11.50	5.75	14.25	20.08	12.9	6.0	6.7	4
	I	7.50	4.00	6.25	7.30	6.2	1.6		
VHF Radio	A	10.33	15.33	14.67	13.00	13.3	2.2	5.7	3
	I	9.00	6.67	7.33	7.47	7.6	1.0		
ADF Radio	A	6.60	5.60	7.60	7.92	6.9	1.0	.6	5
	I	7.40	5.80	6.20	10.52	7.5	2.1		
IFF Tbonspowder	A	11.00	10.70	9.50	14.83	11.5	2.3	3.0	4
	I	7.50	8.75	7.25	10.48	8.5	1.5		
ICS Change Only	A	4.20	3.80	7.20	6.06	5.3	1.6	1.3	5
	I	5.60	2.40	9.80	11.26	6.6	3.2		

A= Data from AAH
I= Data from IACS
Δ= Difference detween A and I
*= Mean average of N data points

APPENDIX B

MISSION COMMUNICATIONS

CEOI HANDOUT

SUBJECT INSTRUCTIONS

WHO ARE YOU?

You are a pilot/commander of an attack helicopter. Your name is SAM and you have a call sign of whiskey six romeo three eight (W6R 38), your wing men are W6R 50) and (W6R 15). You are assigned to Alpha Team, (A) Attack Helicopter Company, 1st Attack Helicopter Battalion, 1st Air Cavalry Combat Brigade.

Being part of an air cavalry combat brigade, you are normally not part of a maneuver-element but instead, are placed opcon to the maneuver element.

THIS MISSION

The 2nd Attack Helicopter Company is being opcon to maneuver elements 3rd Brigade. The armored cavalry squadron has made initial contact and are equipped with GLLDS. Air superiority has not been obtained. You are located at the division airfield and are going to fly forward to the 3rd Brigade HQ LTZA via non-directional beacons. There you will land and recieve a briefing on the current situation. You will then fly forward to a holding area and a firing position. There you will work with x-ray 1 JULIETT one five (X1J15) which is a maneuver element GLLD team.

SOME POINTS TO REMEMBER

(1) The call such as (W6R) is assigned to a major element. A suffix is added such as (W6R 15) to designate individual persons or sub-element within the major element. The full call (W6R 15) is used when initially entering a net and when communications are not clear. An abbreviated call of the last letter and the suffix (R15) is used after entering the net.

(2) You will use the air-to-air radio net set up by the local commander for internal communications with your element.

(3) Some parties which you normally contact may not have been preset into your avionics.

(4) The sheets of frequencies and calls will be considered the (CEOI) which you would normally carry with you during the mission.

(5) The ICS positions are: (1) FM#1; (2) UHF; (3) VHF; (4) FM#2. ICS and Position (5) will select ICS.

EQUIPMENT AND PROCEDURE

Most of the display that is in front of you is lightpen sensitive in that touching the desired switch or button with the lightpen and pushing the small button on the lightpen will simulate activating the switch or button. The display is in three parts: (1) the status panel on top, (2) the primary control panel in the middle, and (3) the ICS panel on the bottom. The ICS panel selects the radio on which you desire to transmit and the status panel displays the frequency or channel that you have selected. You will have an informal training time to learn how to operate the equipment and are free to ask questions and offer suggestions.

During the experiment itself, a voice message will be given to you which will request that you contact certain parties. You may write down or simply remember the party to be contacted. After the message has stopped and you understand what needs to be accomplished, roger the message by pressing any button on your right. The display itself is inactive to the lightpen until you roger the message. The following must be done correctly before you can communicate:

Turn radio on

Turn cipher unit on

Set cipher unit in secure mode

Select correct net variable

Select correct frequency

Set ICS switch to the correct radio

Push any switch on your right again to simulate transmitting.

Normally, if everything is accomplished correctly you will be given another message. If one or more of the above are invalid, you must correct the error in order to communicate.

A message to function the IFF will contain the word (squack) which means you must identify your aircraft by functioning the ident switch.

Some of the message content has been altered to relay information to you.

THE CORRECT MODE OF OPERATIONS FOR THE AVIONICS

1. Turn on all radios and devices.

2. Set applicable radios to TR plus guard.

3. Secure all transmissions.

4. (IFF) change standby to normal.

5. Turn on all modes except mode 4A, preset (31) into mode 1 and (1750) into mode 3.

COMMUNICATIONS S[illegible]

UHF AM TRANSCEIVER

CHANNEL	PARTY	CALL	FREQUENCY	NET VARIABLE
1	FARP #1(GROUND SUPPORT)	F2R43	225.025	3
2	FOC	R5F02	254.050	2
3	DIV AIRFIELD (GROUND CONTROL)	X1J55	246.925	2
4	ATTACK AIR	H9E	382.500	4
5	A COMPANY COMMAND POST	F2R19	235.975	3
6	FORWARD AIR CONTOLLER	Y4M05	379.000	2
7	DIVISION ATC (ENROUTE)	Y4M07	305.125	4
8	BRIGADE AIRFIELD (ATC/TOWER)	X1J09	347.325	2
9	FARP #2(GROUND SUPPORT)	F2R47	395.000	3
10	DIV AIRFIELD (TOWER)	X1J60	305.750	2
ADDITIONAL	FREQUENCIES			
	AIR CAV RESUPPLY	C6A	302.050	5
	BRIGADE(SPARE)	K8U01	236.400	3
	MED EVAC	XOH	225.800	3
	3/16 CAV SQDN COMMAND POST	T0117	375.975	2

CEOI

VHF AM TRANSCEIVER

CHANNEL	PARTY	CALL	FREQUENCY	NET VARIABLE
1	5TH BRIGADE	MOA	121.600	5
2	FARP #1(GROUND TO AIR)	F2R47	148.025	1
3	FCC #1 (BRIGADE)	R5F11	118.550	4
4	6TH BRIGADE	M1B	131.500	5
5	METRO	Y4M05	120.000	4
6	FCC(DIVISION)	R5F17	141.000	4
7	ATTK HELO (A) COMPANY(COMD/OP)	F2R	[illegible]	[illegible]
8	SCOUT HELO PLATOON COMD/OP(SPARE)	VOC	135.875	[illegible]
9	3RD ATTK HELO PLT (SPARE)	J3E	[illegible]	[illegible]
10	2ND ATTK HELO PLT (SPARE)	P8L	[illegible]	[illegible]

ADDITIONAL FREQUENCIES

	FARP #2(GROUND TO AIR)	F2R43	116.975	1
	FCC #2 (FORWARD)	R5F31	145.225	1

CEOI

FM TRANSCEIVER #1

CHANNEL	PARTY	CALL	FREQUENCY	NET VARIABLE
1	COMD/OP NET ATTK HEL(BAT)	K8V	37.95	3
2	FARP (1+2) GROUND SUPPORT	F2R	61.75	3
3	(A) CO 1ST PLATOON(COMD/OP NET)	H2Q	72.25	3
4	(COMD/OP NET) BRIGADE HQ	WGR	35.05	4
5	(COMD/OP NET) (A) CO, ATTK HEL	F2R	41.45	3
6	(B) CO MANEUVER ELEMENT(SPARE)	D9V	60.00	2
7	(A) CO 1ST PLATOON (SPARE)	I2R	53.55	3
8	A CO MANEUVER ELEMENT (SPARE)	X1J	72.05	2
9	AIR CAV SQUADRON(COMD/OP NET)	K8V	52.65	3
10	(A) CO ATTK HELO(AIR TO AIR) (ENROUTE)	W6R	38.85	3

FM TRANSCEIVER #2

CHANNEL	PARTY	CALL	FREQUENCY	NET VARIABLE
1	(B) COMPANY ATTK HELO AIR TO AIR	BOJ	31.40	3
2	FIRE TEAM ALPHA (PRIMARY)	H9R	62.65	3
3	(C) CO ATTK HELO(COMD/OP)	I8C	73.15	3
4	FIRE TEAM BRAVO	W6R	34.00	3
5	FCC/CRC(SECONDARY)	R5F02	42.35	1
6	ATTK HELO BAT (SPARE)	K8V	61.95	3
7	GLLD TEAM(SPARE)	X1J	54.45	3
8	GLLD TEAM (DELTA)	X1J15	73.25	3
9	GLLD TEAM (BRAVO)	X1J27	53.55	3
10	GLLD TEAM(CHARLIE)	X1J33	39.75	3
ADDITIONAL FREQUENCIES				
	D COMPANY	AOI	62.25	2
	RESUPPLY	BOF	63.60	3
	DIVISION SUPPLY	C1H	69.95	5

CEOI

CHANNEL	ADF BEACONS	
1	A	0950.0
2	B	2515.0
3	C	1835.0
4	D	1905.0
5	E	2150.0
6	F	0750.0
7	G	0700.0
8	H	0900.0
9	I	1150.0
10	J	0850.0
	K	1770.0
	L	2100.0
	M	1110.0
	N	1212.0
	O	0880.0
	P	0920.0

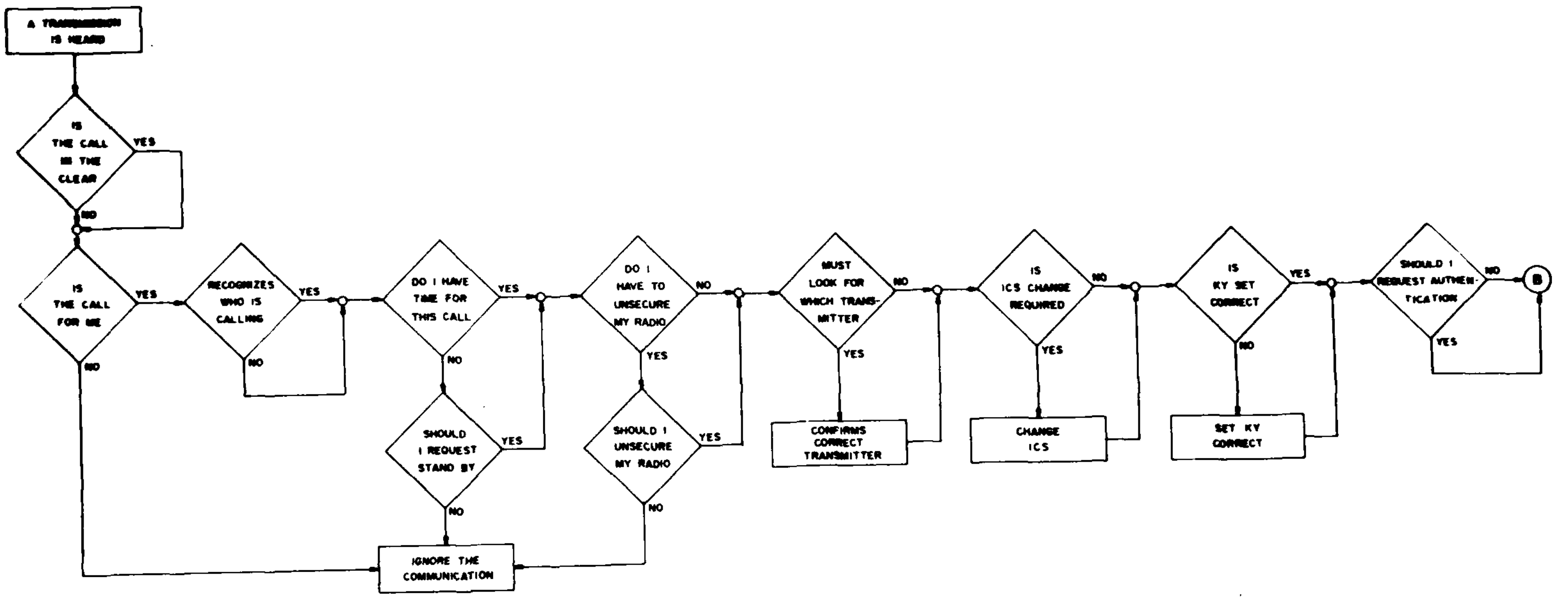
APPENDIX C

COMMUNICATIONS DIAGRAMS

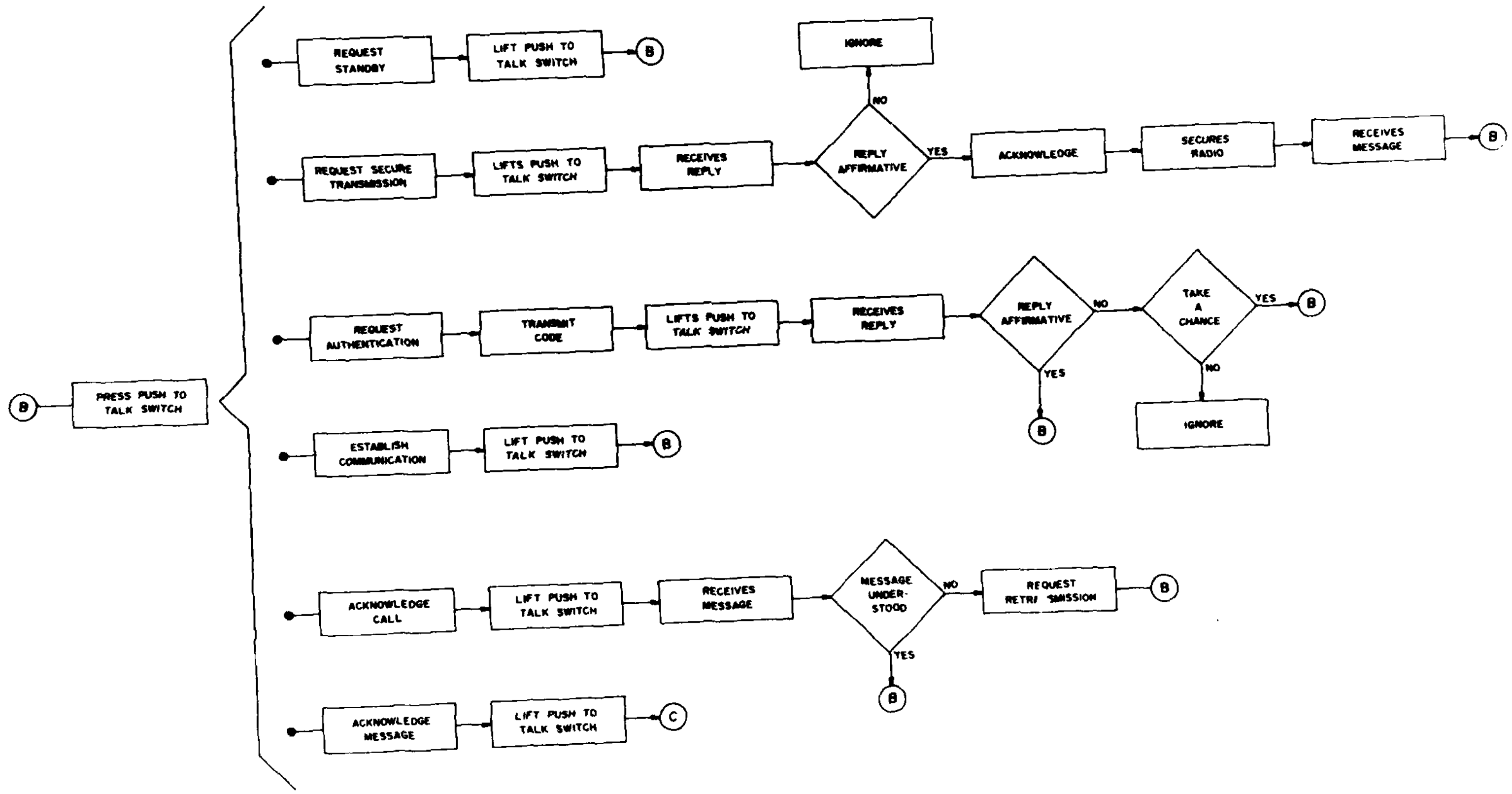
The steps the operator takes as a result of a request to communicate are shown from the beginning on page 43 to point D on page 45.

A comparison of steps taken when using the two different IACS and two standard avionics configurations are from point D to point E. Page 46 is typical ASH or UH1 Helicopter with an ARC 164 radio. Page 47 is the same helicopter without the ARC 164 radio. Pages 48 and 49 compare the two different IACS and show the process by which operators enter a manual frequency.

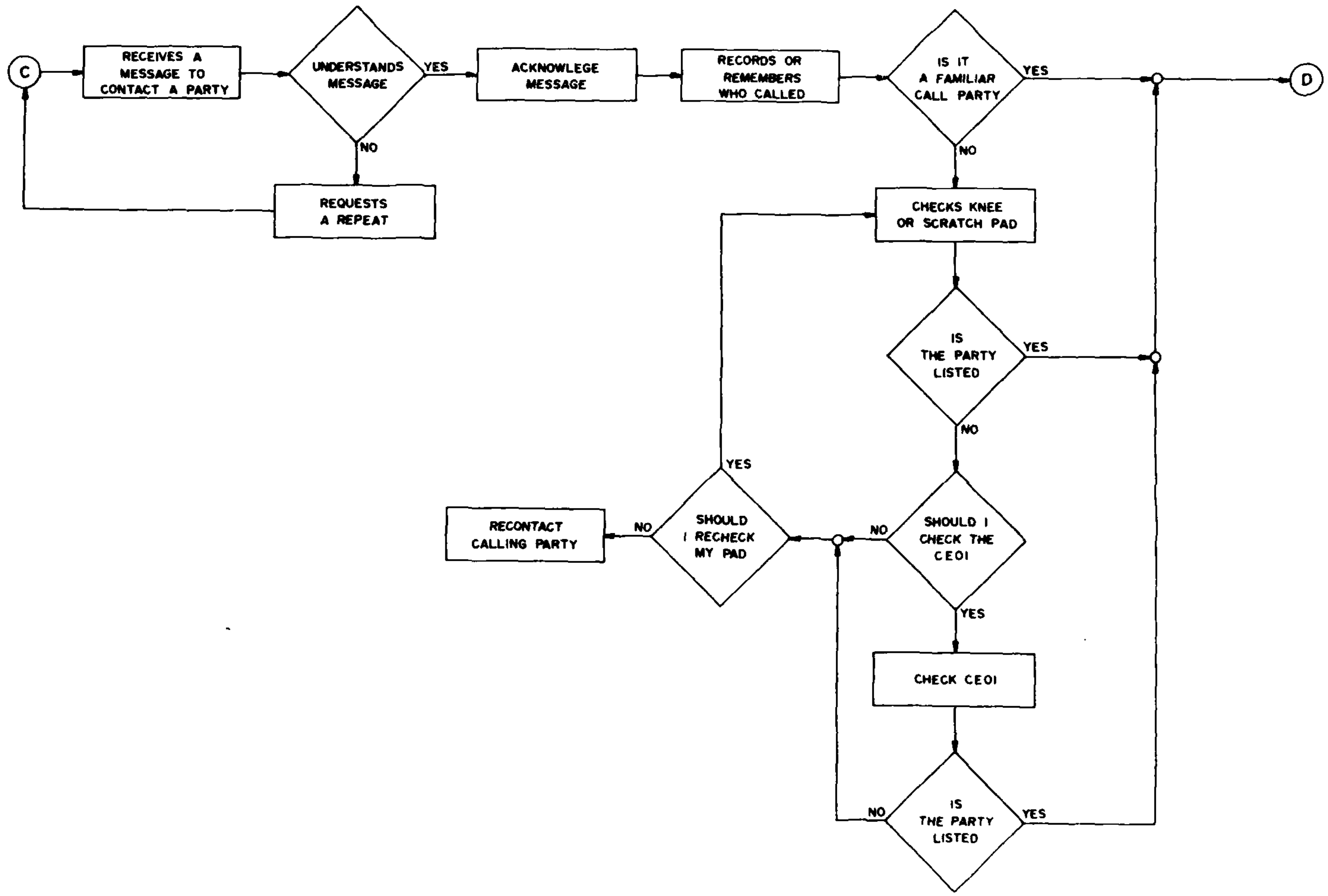
HEARS A TRANSMISSION



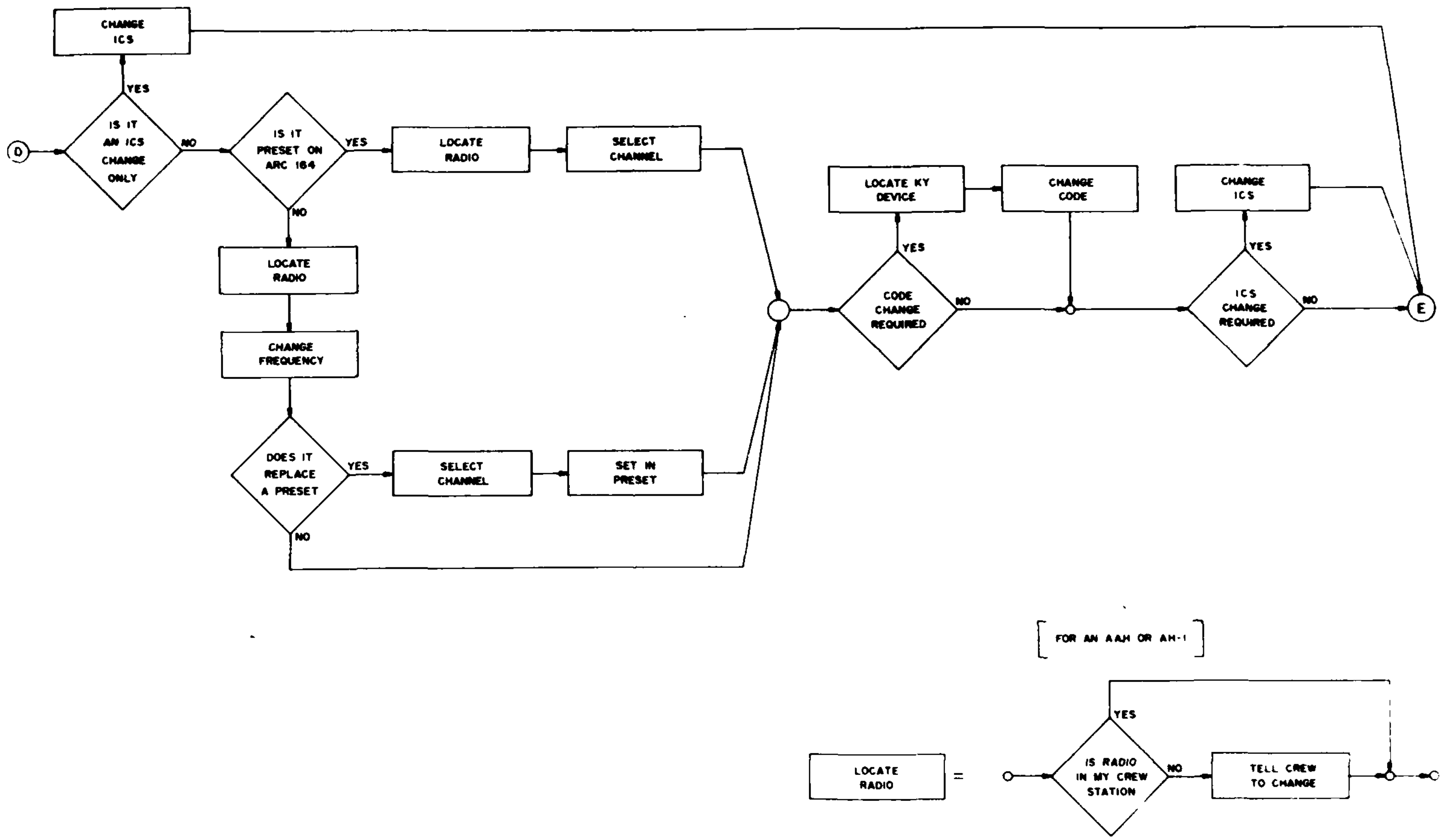
REPLIES TO THE TRANSMISSION



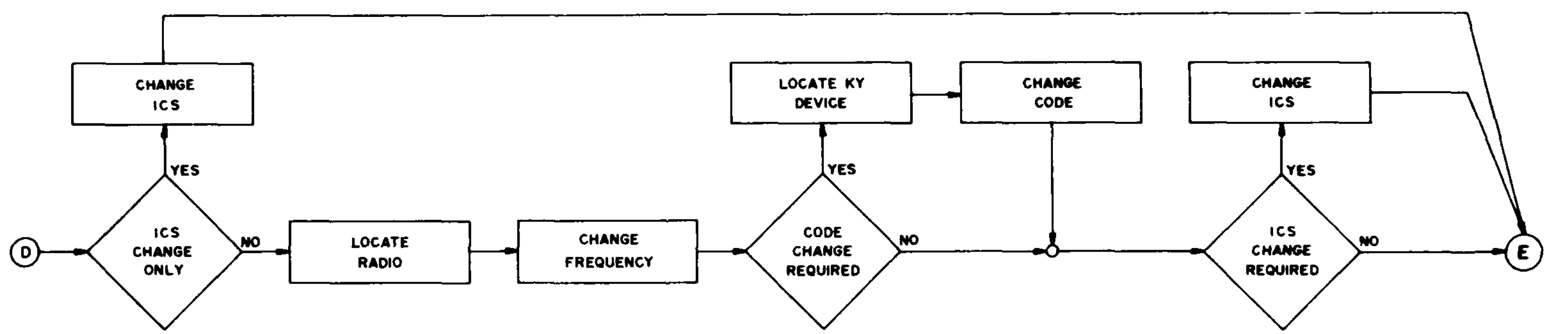
PROCEDURE PRIOR TO
ACCESSING RADIOS



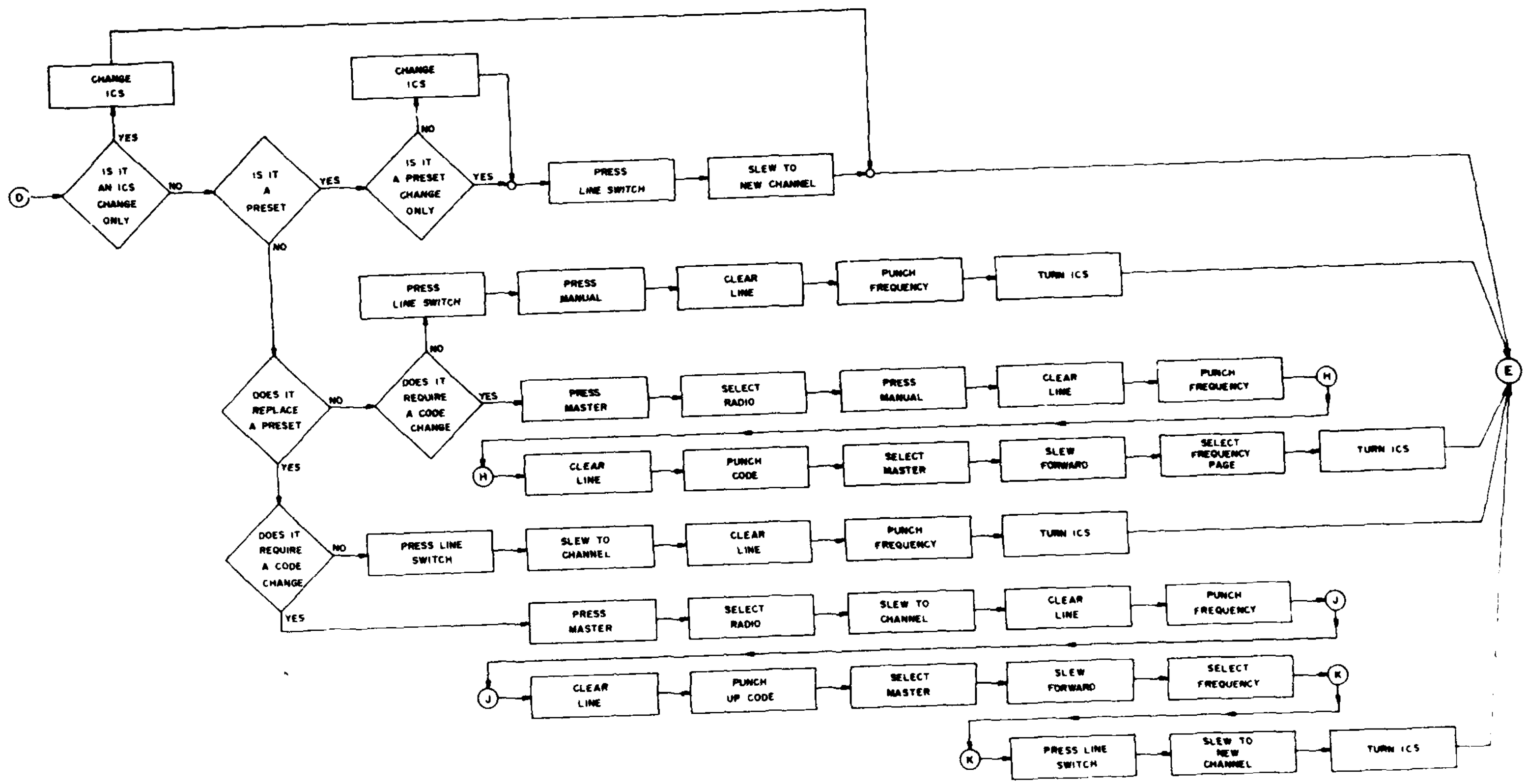
PROCEDURE FOR
ASH AND/OR UH-1 HELICOPTER
EQUIPPED WITH AN ARC-164 RADIO



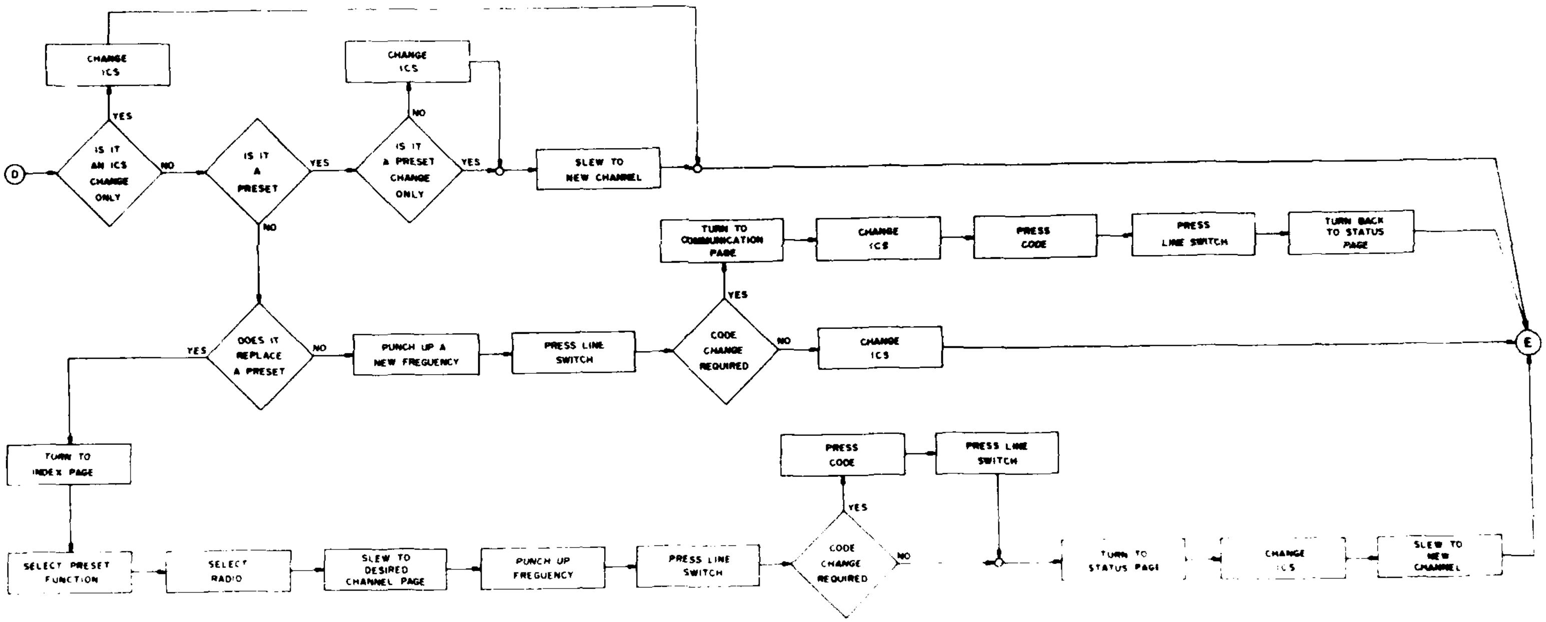
PROCEDURE FOR
ASH OR UH-I HELICOPTER
EQUIPPED WITH BASIC RADIOS

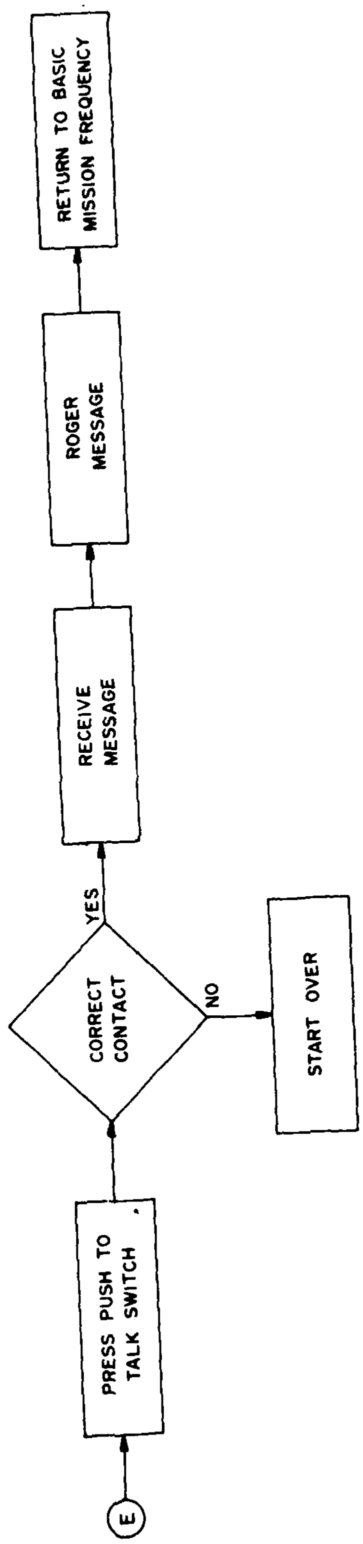


PROCEDURE FOR I.A.C.S.
MODEL A



PROCEDURE FOR I.A.C.S. MODEL B




E
PRESS PUSH TO TALK SWITCH
CORRECT CONTACT
YES
NO
START OVER
RECEIVE MESSAGE
ROGER MESSAGE
RETURN TO BASIC MISSION FREQUENCY

LIST OF ABBREVIATIONS

AAH	Advanced Attack Helicopter
ADF	Automatic Direction Finder
ASH	Advanced Scout Helicopter
AVRADA	Aviation Research and Development Activity
CEOI	Communications Electronics Operating Instructions
FM	Frequency Modulation
HEL	US Army Human Engineering Laboratory
IACS	Integrated Avionics Control System
ICS	Intercommunication System
IFF	Identification Friend or Foe
SOP	Standard Operating Procedure
UHF	Ultra High Frequency
VHF	Very High Frequency
FEBA	Forward Edge of the Battle Area